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We see that the values obtained by actual observation are always greater than those obtained under the assumption that only accidental causes influence the averages for each class. We also see that these causes reach a maximum during the period of growth and decrease as the adult stage is reached. The maximum is found in the fourteenth year in the case of boys, in the twelfth year in the case of girls, *i. e.*, in those years in which the effects of acceleration and retardation of growth are strongest. Although the values given here cannot claim any very great weight on account of the small number of classes, this phenomenon is brought out most clearly.

The figures prove, therefore, that the differences in development between various social classes are, to a great extent, results of acceleration and retardation of growth which act in such a way that the social groups which show higher values of measurements do so on account of accelerated growth, and that they cease to grow earlier than those whose growth is in the beginning less rapid, so that there is a tendency to decreasing differences between these groups during the last years of growth.

FRANZ BOAS.

#### *THE PROMISE AND POTENCY OF HIGH-PRESSURE STEAM.*

THE writer has been so fortunate, recently, as to be permitted to study the action of exceptionally high-pressure steam in the engine, under favorable conditions, and thus to add to the record of Jacob Perkins and his sons, and of Dr. Albans and others experimenting with steam of extraordinarily high-pressure, data which represents much more satisfactorily the conditions now known by the engineer to be those essential to economic operation.\*

\*The 'Promise and Potency' of high-pressure steam; illustrated by the performance of the triple, and the quadruple-expansion experimental engines of Sibley College. *Trans. Am. Soc. M. E.*, December, 1896. Vol. XVIII; No. DCCXVIII.

The progress made to date and during the century now elapsed since the introduction by James Watt of the modern type of steam-engine, as adapted to the performance of every variety of work, has been mainly through the steady advances effected in the successful management and application of steam of increasing pressure, with corresponding thermodynamic gain by increasing the ratio of expansion, and with reduction of wastes, mainly by increasing speeds of engine. The accessory gains have been through expedients for improving the lubrication, to reduce wastes of dynamic energy, and for securing better protection against external losses of thermal energy, and improvements, as by jacketing and superheating, resulting in suppression of the internal condensation, due to the action of the cylinder wall.

Increasing steam pressure gives increased mean effective pressures, and rising temperatures of steam afford gains by widening the range of adiabatic and thermodynamic transformation of energy. Superheating has not, as yet, been successfully carried so far as to permit increased thermodynamic transformation by providing a steam gas as the working fluid in the engine. It practically simply insures dryer, and thus better, working steam. Up to the present time the risings, temperatures and expansions have gone together, being limited by the conditions which give us dry and saturated steam. The result has been a steady advance for a century, both in the 'duty' of the machine and its complementary elements, thermodynamic and mechanical efficiency. Watt insisted on restricting steam pressure to seven pounds per square inch on the score of safety; we now employ from twenty to thirty times that pressure with probably no greater risk. The work described in the communication here abstracted was done at 300 to 500 pounds pressure, and the boiler employed had been

tested up to 1,350 pounds and operated, with the engine, at times, at above 600 pounds pressure. But even these working pressures are comparatively low figures beside those of Perkins, who sixty years ago operated steam engines at 1,000 and 1,500 pounds and upward, and whose disciple, Dr. Albans, built a number of engines for regular work at nearly as great tensions of steam. Owing to their incomplete expansion, and owing to the fact that they were not compounded or otherwise insured against great 'cylinder condensation,' the engines of neither of these experimentalists attained what would be to-day thought remarkable economy. It was, however, remarkable for their time.

In those early days a piston speed of '128 times the cube root of stroke' was standard practice; the figure has now risen to, in some instances, four times this figure, and standard practice ranges from 600 feet, with small 'automatics,' to 1,000 feet per minute in large engines. The size, weight and cost of the machine for any stated power have been correspondingly diminished. The main source of gain in the meantime has been the diminution of the internal thermal wastes of the machine, which constituted in the days of Watt ninety per cent. or more of the demand for steam in the old Newcomen engine which he reconstructed, thirty to forty per cent. of the steam consumption in his own engines, and which has now fallen in the best contemporary machines to about twenty per cent., still constituting an important source of loss. 'Duty' has risen from about 10,000,000 foot-pounds in the first of these series to 60,000,000 in the second, and has attained to-day about 150,000,000 and promises to become 160,000,000 at the end of the century, per hundred pounds of best coal consumed. Reduced to steam consumed, the latter figures correspond to about eleven and a-half

and about eleven pounds per horse-power per hour, and, in heat expended, about as many thousand B. T. U., with high temperature feed-water with large proportion, or ten per cent. more with moderate admixture, of jacket water. In fuel, it corresponds to from  $1\frac{1}{4}$  to  $1\frac{3}{4}$  pounds per I. H. P. per hour. The average steam engine of even good makers seldom attains much more than one-half the efficiency of the modern record-making machines.

The triple-expansion engine of Sibley College, built and employed as an experimental engine purely, illustrates the action of good engines at about 125 pounds pressure (absolute). It gives the indicated horse power on about 13.3 pounds of steam, 15.1 per D. H. P., and 14,160 B. T. U. per hour; its total ratio of expansion being 13.83, and the jackets supplying 13.72 per cent. of the feed water. The thermodynamic efficiency of the corresponding Carnot Cycle would be 24.7 per cent.; that of the engine is 18 per cent. A low vacuum, 22 inches, makes this work still more remarkable for so small an engine. It operated at 140 I. H. P. in this case. The machine was built for 175 pounds steam—another disadvantage. The dictum of Dwelshauver-Dery and the writer, that the jackets produce best effect, and efficiency attains a maximum, when the expanding steam is dry at or before final exhaust into the condenser, is confirmed by these results. The jackets are in this engine always advantageous.

The records first given, as the present maxima, are from large engines operated at from 125 to 175 pounds pressure. Those are triple-expansion. The following are data relating to the quadruple-expansion experimental engine of Sibley College, Cornell University, operated at, in some cases, 500 pounds pressure and upward. The machine is of but twenty horse-power rating; its cylinders having diameters of respec-

tively 2.344, 3.969, 6.977 and 10.266 inches; the stroke of piston being 4.5 inches, and its speed of revolution usually about 300 per minute. The engine possesses a number of interesting and ingenious new devices introduced by its designers and builders, Messrs. Hall and Treat, graduate students of the College; and its boiler, a water-tube construction, is also original in plan.

The trials of this engine, conducted under many difficulties, and often at some hazard, in consequence of perpetual trouble met with, in the early part of its history, in securing a reliable means of feeding against the high boiler-pressure, and in finding a good method of obtaining water-level indications, resulted in showing an exceedingly low steam and heat consumption. After a good feed pump had been secured, and the boiler could be handled with safety and without anxiety, and after the constructors had devised a new and reliable system of water-level indication, trials were carried on, the outcome of which has now been published. The net result was the indication of a pressure of maximum efficiency, for this engine, less than that for which it was designed, and the obtaining, at best adjustments, of an efficiency of about thirty per cent., a steam consumption of about ten pounds per I. H. P. per hour, and of 226 B. T. U. per I. H. P. per minute, 13,560 per hour, at 300 and 400 pounds pressure. The engine was provided with 'reheaters,' or drying chambers, between each pair of cylinders, and, these being thrown out and the steam worked wet, the consumption rose to from 13.7 pounds at 500 pounds pressure to 15.5 at 300 pounds, per I. H. P. per hour. The wastes in the latter case were substantially the same at high as at low pressures, and the deduction follows that we may expect at high steam pressures about as close an approximation to the ideal thermodynamic case as at ordinary

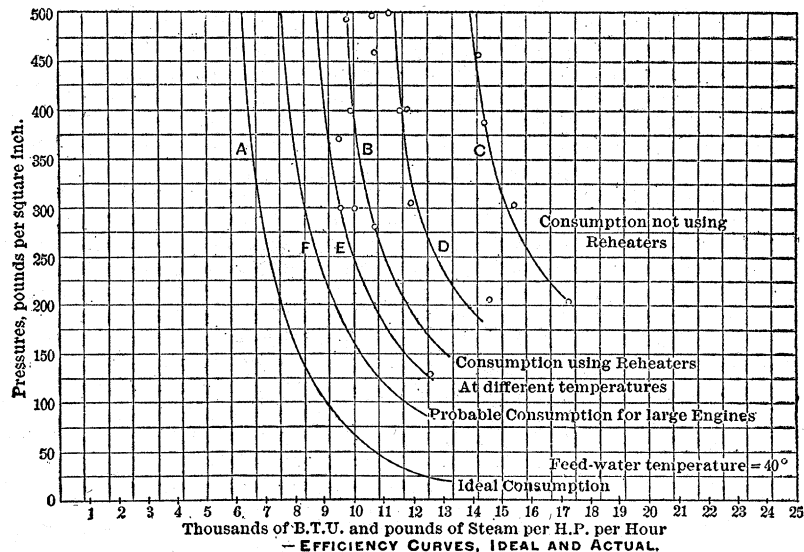
tensions of steam. There still remains, however, some question as to the exact efficiency of even this engine; owing to irregularity and shortness of most of the trials, due to the difficulties with the boiler above mentioned, and some uncertainty regarding leakage past piston and valves; the existence of which is at least indicated by the measurements of the indicator diagrams.

A comparison of these figures with those of larger engines in commercial use can only be made after allowing for the comparatively large internal wastes, due to the excessive proportion of area of cylinder wall to weight of steam passing through the engine, in the case of small machines. Reducing these wastes by any probable fraction, the heat, steam and fuel consumption of the engine at its regular pressure, above thirty-three atmospheres, would give a consumption of not far from  $7\frac{1}{2}$  pounds of steam per I. H. P. per hour, or from 7,500 to 8,000 B. T. U., according to temperature of feed water.

The diagram herewith presented shows the relation of the efficiency of the ideal, purely thermodynamic, engine of similar cycle—the Rankine form—to the actual performance. The curve *A* is that of the best ideal, case *B* that of the average best performance of the experimental engine, *C* that with its reheaters out of use, and the various observations indicated on the chart show the variations due to varying efficiency of reheating and to other variable conditions of operation. *D* may be taken as representing fair average performance, and *E* the limit of best work; while *F* is not far from what should be expected from large engines of similar type, and is taken as representative of the commercial attainable performance of such good practice at 500 pounds pressure and under.

These curves of relation of steam used to power produced are of the form

$$w = a / \log p;$$



where the value of  $a$  varies from 18 on the line  $A$ , to 25 on  $B$ , 30 on  $C$ , and to 22 and 24 on lines  $F$  and  $E$ ;  $w$  being weight of steam per h. p. per hour,  $p$  steam pressure.

Of the figures representing efficiency, as here recorded, it is probable that those on the line  $C$  may be accepted as accurate. Those obtained with reheaters in use are obviously less certain, and may be subject to some error. On the whole, the writer considers that the assignment of the lines  $E$  and  $F$  as those to be attributed to successful practice with large engines, and as representing the 'promise and potency' of high-pressure steam, is well justified.

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#### THE ORIGIN OF THE TEETH OF THE MAMMALIA.

PROFESSOR H. G. SEELEY, F.R.S., in a series of memoirs in the *Philosophical Transactions*, during the past three or four years, has been describing the Upper Triassic vertebrates of South Africa. Certain of these animals are upon the border line between the Reptiles and Mammals, and, as Professor Seeley points out, show a most remarka-

ble intermingling of characters. The cranial characters, with the exception of the paired occipital condyle, are mainly reptilian; the dental characters, and this is the point to which I wish to especially draw attention, are pro-mammalian. The point of particular interest is that within this group are found *all the primitive mammalian types of teeth*. *Lycosaurus* is haplodont; *Galesaurus* *Cynognathus*, both members of the *Cynodontia* or Carnivorous division, are *triconodont*. The teeth are as clearly divided into incisors, canines, premolars and molars as those of the lower Jurassic mammals. The dental formula approximates that of the stem mammal. These animals parallel or are actually related to the great 'protodont-triconodont-trituberculate' phylum of mammalia, which includes the Marsupials and Placentals. In a distinct division of herbivorous reptiles, which Seeley terms the *Gomphodontia*, we find a corresponding parallel or ancestral relation to the 'multituberculate' phylum of mammals, including the Multituberculata and possibly the Monotremata. Here, in fact, actually belongs *Tritylodon*, which upon good grounds has, until recently, been considered a multitu-